Original Article

Skeletal Sagittal and Vertical Facial Types and Electromyographic Activity of the Masticatory Muscle

Bong Kuen Cha[a]; Chun-Hi Kim[b]; Seung-Hak Baek[c]

ABSTRACT

Objective: To investigate the electromyographic activities of the anterior temporal (T) and masseter (M) muscles in different facial skeletal types.

Materials and Methods: The samples consisted of 105 subjects (38 males and 67 females; mean age 22.0 ± 6.7 years) and were classified into six groups according to the values of ANB and SN-GoMe: group 1 for Class I malocclusion and normodivergent type (n = 27), group 2 for Class I and hyperdivergent type (n = 20), group 3 for Class II and normodivergent type (n = 10), group 4 for Class II and hyperdivergent type (n = 23), group 5 for Class III and normodivergent type (n = 12), and group 6 for Class III and hyperdivergent type (n = 13). Temporal muscle activity (TMA), masseter muscle activity (MMA), and T/M ratio were evaluated at resting and clenching status.

Results: Although there was no significant difference in resting MMA among all groups, group 6 showed a higher resting TMA than did other groups and a significant difference in resting T/M ratio compared with groups 1 and 3. There were no significant differences in clenching TMA and MMA among all groups. Although all groups showed a significant increase of TMA and MMA from resting to clenching status, group 6 showed a significant decrease of clenching T/M ratio compared with resting T/M ratio.

Conclusions: The results suggest that the more Class III and the more hyperdivergent type, the higher resting TMA and the lesser increase of clenching MMA than expressed by other groups. Significant differences existed in TMA and MMA according to sagittal and vertical facial skeletal types.

KEY WORDS: Masseter muscle; Temporal muscle; Electromyogram; Facial skeletal type

INTRODUCTION

It has been widely accepted that function of the masticatory muscle has a considerable influence on craniofacial morphology.[1–18] Also, craniofacial morphology is known to be related with biting force[2,9,10,15,19] or with resting activity of the masticatory muscle.[14,20–23]

In the study of the relationship between Angle classification of malocclusion and the masticatory muscle activity, Miralles et al[14] reported that resting activity for masticatory muscle was higher in subjects with Class III malocclusion than in subjects with Class I and II malocclusion. However, during maximal voluntary clenching (MVC), activity was not different among Class I, II, and III malocclusions.[14] On the contrary, Antonini et al[24] indicated that significant differences in masticatory muscles activity during mastication and swallowing were observed between the Class II division 2 malocclusion group and the Class III malocclusion group and that there was no significant difference between Class II and Class III malocclusion groups at rest. Lowe and Takada[25] reported that significant canonical correlations could not be found between the cephalometric data and clench, swallow, or jaw-opening tasks.

[a] Associate Professor, College of Dentistry, Department of Orthodontics, Kangnung National University, Kangnung, Kangwondo, South Korea.

[b] MS graduate student, College of Dentistry, Department of Orthodontics, Kangnung National University, Kangnung, Kangwondo, South Korea.

[c] Associate Professor, School of Dentistry, Dental Research Institute, Seoul National University, Department of Orthodontics, Seoul, South Korea.

Corresponding author: Dr Seung-Hak Baek, School of Dentistry, Dental Research Institute, Seoul National University, Department of Orthodontics, Yeonkun-dong #28, Jongro-ku, Seoul, South Korea 110-1768 (e-mail: drwhite@unitel.co.kr)

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TABLE 1. Classification of the Groups According to the Skeletal Sagittal and Vertical Facial Types

	Class II Group (ANB > 4°)	Class I Group (0° < ANB < 4°)	Class III Group (ANB < 0°)
Hyperdivergent group (SN-GoMe > 36°)	Group 4 (n = 23) 3 males, 20 females	Group 2 (n = 20) 8 males, 12 females	Group 6 (n = 13) 5 males, 8 females
Normodivergent group (22° < SN-GoMe < 36°)	Group 3 (n = 10) 2 males, 8 females	Group 1 (n = 27) 11 males, 16 females	Group 5 (n = 12) 6 males, 6 females

Figure 1. Electromyographic recordings with the K6-I system.

In a study of the relationship between vertical facial type and the masticatory muscle activity, Ahlgren et al[3,12] reported that the mandibular plane angle (SN-GoMe) was positively correlated to the temporal muscle activity (TMA). Ueda et al[16] suggested that masseter muscle activity (MMA) showed significant negative correlations with vertical craniofacial morphology, whereas TMA was positively correlated. Kayukawa[26] indicated that the muscle activities were significantly higher in deep-bite patients than in patients with other malocclusion types.

Liebman[27] concluded that during the mandibular movements there was no specific pattern of muscle function in individuals with normal occlusion or in those with malocclusions. On the other hand, MacDonald and Hannam[28] reported that there were significant activities of temporal muscle in retrusive clenching and the masseter muscle in protrusive and incisal clenching, with very low activity in the other muscles.

Controversy about the relationship between masticatory muscle activity and craniofacial morphology seems to be due to differences in criteria for sample selection, such as skeletal or dental classification, age, sample size, and individual variation in the masticatory muscle activity. Therefore, to compare the electromyography (EMG) activity of the masticatory muscle in the diverse skeletal patterns, it is necessary to classify the skeletal type according to the vertical and sagittal characteristics. To ensure the integrity of the muscle activity, it is necessary to investigate muscle activities at rest and during clenching. Also, enough size of sample that was properly classified is a prerequisite of the study.

The purpose of this study was to investigate the EMG activities of the masseter and anterior temporal muscles in different skeletal sagittal and vertical facial type.

MATERIALS AND METHODS

The sample consisted of 105 subjects (38 males and 67 females; mean age 22.0 ± 6.7 years) who were registered at the Department of Orthodontics,

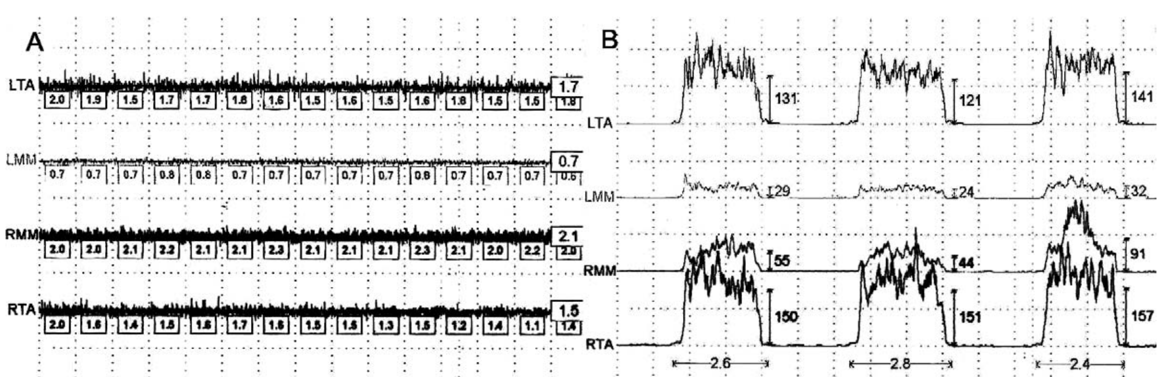

Figure 2. The electromyography activity at rest (A) and during clenching (B). TA indicates anterior temporal muscle; MM, masseter muscle; L, left; and R, right.

TABLE 2. Topography of the Groups According to Age, ANB, and SN-GoMe[a]

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6			
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Significance	Scheffe Multiple Comparison Test
Age, y	23.15	8.11	20.18	5.22	23.99	9.64	23.58	5.59	19.83	4.61	20.44	5.65	0.2700	NS
ANB, °	2.08	1.31	2.06	1.24	5.64	1.12	6.20	1.96	−2.49	2.68	−2.92	1.83	0.0000	(1,3)*, (1,4)*, (1,5)*, (1,6)*, (2,3)*, (2,4)*, (2,5)*, (2,6)*, (3,5)*, (3,6)*, (4,5)*, (4,6)*
SN-GoMe, °	30.69	4.50	40.35	3.11	30.94	3.48	44.13	6.16	30.00	6.26	41.02	4.40	0.0000	(1,2)*, (1,4)*, (1,6)*, (2,3)*, (2,5)*, (3,4)*, (3,6)*, (4,5)*, (5,6)*

[a] Group 1 consisted of samples with $0° < \text{ANB} < 4°$ and $22° < \text{SN-GoMe} < 36°$ ($n = 27$), group 2 with $0° < \text{ANB} < 4°$ and $\text{SN-GoMe} > 36°$ ($n = 20$), group 3 with $\text{ANB} > 4°$ and $22° < \text{SN-GoMe} < 36°$ ($n = 10$), group 4 with $\text{ANB} > 4°$ and $\text{SN-GoMe} > 36°$ ($n = 23$), group 5 with $\text{ANB} < 0°$ and $22° < \text{SN-GoMe} < 36°$ ($n = 12$), group 6 with $\text{ANB} < 0°$ and $\text{SN-GoMe} > 36°$ ($n = 13$). The differences in age, ANB, and SN-GoMe among groups were tested by one-way analysis of variance and verified with Scheffe multiple comparison test. SD indicates standard deviation; NS, not significant.

* $P < .001$.

TABLE 3. Comparison of the Temporal (T) and Masseter (M) Muscle Activities Between Males and Females in Each Group[a]

			Resting activity			Clenching activity		
			T, μV	M, μV	T/M ratio	T, μV	M, μV	T/M ratio
Group 1	Male (n = 11)	Mean	1.73	1.37	1.26	130.95	156.77*	0.84
		SD	1.26	0.72		50.40	76.96	
	Female (n = 16)	Mean	1.75	1.68	1.04	108.35	99.19	1.09
		SD	0.92	0.75		57.14	41.55	
Group 2	Male (n = 8)	Mean	2.10	1.65	1.27	108.06	125.50	0.86
		SD	1.08	0.57		45.13	65.25	
	Female (n = 12)	Mean	2.07	1.65	1.25	106.46	113.17	0.94
		SD	0.91	0.41		34.60	54.79	
Group 3	Male (n = 2)	Mean	1.90	1.58	1.20	82.75	31.50	2.63
		SD	0.28	0.81		37.12	12.02	
	Female (n = 8)	Mean	1.38	1.50	0.92	106.19	116.34*	0.91
		SD	0.49	0.45		40.49	41.19	
Group 4	Male (n = 3)	Mean	2.97	2.38	1.25	113.33	147.17	0.77
		SD	2.22	0.68		87.80	18.75	
	Female (n = 20)	Mean	2.13	1.56	1.37	107.65	89.65	1.20
		SD	1.27	0.68		26.93	50.47	
Group 5	Male (n = 9)	Mean	1.82	1.39	1.31	139.89*	150.72	0.93
		SD	0.51	0.43		46.21	112.59	
	Female (n = 3)	Mean	2.20	1.52	1.45	66.15	77.97	0.85
		SD	0.77	0.28		25.64	71.53	
Group 6	Male (n = 5)	Mean	5.20	2.05	2.54	144.30	89.70	1.61
		SD	3.15	0.73		32.44	26.94	
	Female (n = 8)	Mean	3.09	1.58	1.96	133.81	117.19	1.14
		SD	1.61	0.34		53.17	56.22	

[a] The differences in muscle activity in resting and during maximal clenching between males and females in each group were tested by Mann-Whitney *U*-test. SD indicates standard deviation.

* Means $P < .05$.

College of Dentistry, Kangnung National University, Kangwondo, South Korea, from 1998 to 2003.

The selection criteria were as follows: (1) full permanent dentition, (2) no missing teeth and prosthetics, (3) no previous orthodontic treatment or orthognathic surgery history, (4) no symptoms of temporomandibular joint or jaw-muscle disorders, (5) no cuspal interference and resultant functional shift of the mandible,

TABLE 4. Comparison of Temporal (T) and Masseter (M) Muscle Activities Among Groups[a]

		Group 1		Group 2		Group 3	
		Mean	SD	Mean	SD	Mean	SD
Resting activity	T, μV	1.74	1.04	2.08	0.95	1.49	0.49
	M, μV	1.55	0.74	1.65	0.47	1.52	0.48
	T/M ratio	1.12		1.26		0.98	
Clenching activity	T, μV	117.56*	54.67	107.10*	38.00	101.50*	39.06
	M, μV	122.65*	64.08	118.10*	57.84	99.38*	51.14
	T/M ratio	0.96		0.91		1.02	

[a] The differences in electromyography activities of the T and M muscles at rest and during maximal clenching in each group were tested by one-way analysis of variance and verified with Scheffe multiple comparison test. The muscle activities between resting and clenching in group 1 were examined with paired *t*-test and in groups 2 through 6 with Wilcoxon signed rank test. SD indicates standard deviation.

* $P < .001$; ** $P < .01$; *** $P < .05$.

(6) no unilateral masticatory habit, and (7) no severe skeletal facial asymmetry (<4 mm).

Lateral cephalograms were taken in the centric occlusion with reposed lips. The sagittal and vertical differences between the maxillary and mandibular apical bases were measured with ANB and mandibular plane angle (SN-GoMe). All measurements were calculated to the nearest 0.005°. These variables were reassessed again after 2 weeks by a single observer. Paired *t*-test showed that there was no difference between the two assessments ($P > .05$); therefore, the latter assessment was used.

The sagittal relationship was divided into skeletal Class I group (0° < ANB < 4°), Class II group (ANB > 4°), and Class III group (ANB < 0°). The vertical relationship was divided into normodivergent group (22° < SN-GoMe < 36°) and hyperdivergent group (SN-GoMe > 36°). Samples were classified into six groups according to the values of ANB and SN-GoMe (Table 1).

EMG recordings were made with the K6-I diagnostic system (Myotronics-Noromed, Seattle, Wash) (Figure 1). Each subject sat upright in a dental chair with his or her head supported and the FH (Frankfurt) plane parallel to the floor. To record EMG activity of the superficial masseter muscle, two electrodes per side were placed according to the direction of the masseter muscle fibers 1 cm above and below the motor point on a line running parallel to the ear border (tragus) across the motor point. For the anterior temporal muscle, two electrodes per side were attached about 1 cm above the zygomatic arch and 1.5 cm behind the orbital border. TMA and MMA of the right and left sides were recorded at rest and during MVC (Figure 2). Resting EMG activities of those muscles were measured for a period of 15 seconds, and averages of signals were obtained by using the K6-I system. To minimize psychological factors,[14] the subjects were instructed to clench as hard as they could. Three 15-second MVC trials were evaluated, with an interval of 1 minute to avoid muscular fatigue, and the mean value of three MVC values of signals was recorded. We evaluated not only the amplitude of TMA and MMA but also the ratio of TMA and MMA (T/M ratio) at rest and during clenching. T/M ratio was used to eliminate bias that could be originated from difference of absolute value between MMA and TMA from individual variation of muscle activity.

Because there were no significant differences in TMA and MMA between the right and left sides, the mean values of those muscle activities of both sides were used.

One-way analysis of variance and Scheffe multiple comparisons were performed to examine differences in age, ANB, SN-GoMe, and EMG activity at rest and during maximal clenching among all groups. The muscle activities between resting and clenching in each group were compared with paired *t*-test and Wilcoxon signed rank test. To investigate the correlation between muscle activity and facial type, Pearson correlation analysis was performed.

RESULTS

Although there was no difference in age among the six groups (Table 2), there were significant differences in the value of ANB among the Class I group (groups 1 and 2), class II group (groups 3 and 4), and class III group (groups 5 and 6) ($P < .001$). There were also significant differences in the value of SN-GoMe between the normodivergent group (groups 1, 3, and 5) and the hyperdivergent group (groups 2, 4, and 6) ($P < .001$) (Table 2). These results suggested that each group was well allocated according to the values of ANB and SN-GoMe.

In resting status, TMA and MMA did not show any difference between males and females in all groups (Table 3). During maximal clenching, MMA showed

TABLE 4. Extended

Group 4		Group 5		Group 6			
Mean	SD	Mean	SD	Mean	SD	Significance	Scheffe Multiple Comparison Test
2.24	1.39	1.92	0.57	3.90	2.44	0.0001	(1,6)***, (2,6)*, (3,6)**, (4,6)*, (5,6)
1.67	0.72	1.42	0.39	1.76	0.55	0.7529	(1,6)*, (3,6)*
1.34		1.35		2.22		0.0040	
108.39*	36.48	121.45*	52.77	137.85*	45.04	0.3524	
97.15*	51.23	132.53**	105.99	106.62*	47.74	0.5693	
1.12		0.92		1.29***		0.2969	

TABLE 5. Correlation Between Temporal (T) and Masseter (M) Muscle Activities and Skeletal Sagittal and Vertical Facial Types[a]

	Class I Group		Class II Group		Class III Group		Normodivergent Group		Hyperdivergent Group	
Correlations	ANB	SN-GoME	ANB	SN-GoME	ANB	SN-GoME	ANB	SN-GoME	ANB	SN-GoME
Resting activity										
T	−0.0676	0.0843	0.1609	0.0739	0.0622	0.4557*	−0.1750	−0.1902	−0.2616	−0.0121
M	0.1286	0.0782	0.3429	0.2723	0.1710	0.2170	0.0479	−0.0407	0.1280	0.2329
T/M ratio	−0.1418	−0.0193	0.0227	−0.0056	−0.0638	0.3788	−0.2023	−0.1680	−0.2931*	−0.0924
Clenching activity										
T	−0.0498	−0.1405	0.2497	0.2368	−0.4369*	−0.1403	−0.1823	−0.2450	−0.2549	0.0786
M	−0.0069	0.0869	−0.2048	0.0126	−0.1501	−0.3107	−0.1692	−0.0276	−0.1485	−0.0662
T/M ratio	−0.0191	−0.1959	0.2272	0.0108	−0.0307	0.2043	0.1325	−0.2249	0.0442	0.1243

[a] Class I group consisted of samples with 0° < ANB < 4° (groups 1 and 2, n = 47); Class II group, ANB > 4° (groups 3 and 4, n = 33); Class III group, ANB < 0° (groups 5 and 6, n; = 25); normodivergent group, 22° < SN-GoMe < 36° (groups 1, 3, and 5, n = 49); hyperdivergent group, SN-GoMe > 36° (groups 2, 4, and 6, n = 56). To investigate the correlation between cephalometric measurements and muscle activity, Pearson correlation analysis was performed.

* Means $P < .05$.

significant difference only in groups 1 and 3 ($P < .05$) and TMA only in group 5 ($P < .05$) (Table 3). However, the number of subjects in each group was too small to draw a conclusion of gender difference. In this study, we decided to put the males and females together in each group.

Although there was no significant difference in resting MMA among all groups, group 6 showed higher resting TMA than did other groups (group 1 vs 6, $P <$ .001; group 3 vs 6, $P < .01$; group 2 vs 6, group 4 vs 6, and group 5 vs 6, $P < .05$) (Table 4). This means that the more the Class III malocclusion tendency, the more the hyperdivergent tendency and the higher the resting TMA was expressed.

In the same skeletal vertical facial type group (normodivergent group and hyperdivergent group), there were no differences in resting TMA and MMA among the Class I, II, and III groups (Table 4). Similarly, in the same skeletal sagittal facial type group (Class I, II, and III groups), there were no differences in resting TMA and MMA between the hyperdivergent and normodivergent groups (Table 4).

According to the higher resting TMA, group 6 showed significant differences in the resting T/M ratio compared with groups 1 and 3 (group 1 vs 6 and group 3 vs 6, $P < .05$) (Table 4).

There were no significant differences in clenching TMA and MMA among all groups (Table 4). However, group 6 showed a higher TMA tendency than did the other groups, though there was no statistically significant difference (Table 4).

Although all groups showed a significant increase of clenching TMA (groups 1 through 6, $P < .001$) and MMA (groups 1 through 4 and group 6, $P < .001$; group 5, $P < .01$) compared with the resting TMA and MMA, group 6 indicated a significant smaller clenching T/M ratio than resting T/M ratio ($P < .05$) (Table 4). These findings imply that the more Class III malocclusion tendency, the more the hyperdivergent tendency and the lesser increase of clenching MMA than expressed by the other groups.

In the Class III group (groups 5 and 6), resting TMA was positively correlated with SN-GoMe ($P < .05$) and clenching TMA and negatively correlated with ANB ($P < .05$) (Table 5). These findings mean that the resting TMA increased according to the increase of hyperdivergency tendency and clenching TMA increased according to the increase of Class III tendency. In the hyperdivergent group (groups 2, 4, and 6), resting T/M ratio was negatively correlated with ANB ($P < .05$) (Table 5). This suggests that the resting T/M ratio increased according to the increase of Class III tendency.

DISCUSSION

There has been an inconsistency in the findings reported in previous EMG studies conducted to determine the relationship between masticatory muscle function and craniofacial morphology.[1,5–8,29–32] Miralles et al[14] reported high correlations between EMG activity and ANB angle and overjet. Deguchi et al[33] indicated that, compared with normal subjects, patients with a Class III malocclusion had a demonstrably abnormal masticatory muscle balance.

Ingervall and Thilander[4] insisted that the considerably larger muscle activity belonged to a brachyfacial skeletal pattern. Therefore, both vertical and sagittal components of craniofacial morphology should be considered together to more clearly elucidate the relationship between masticatory muscle activity and craniofacial morphology.

There was much controversy regarding the pattern of resting EMG activity in relation to skeletal sagittal and vertical facial types. For example, in terms of resting EMG activity in Angle classification of malocclusion type, Antonini et al[24] and Miralles et al[14] reported the opposite results. Also, for the vertical aspect, Ahlgren et al[3,12] and Lowe et al[34] showed contradictory correlations results between craniofacial morphology and resting EMG activity.

The higher resting TMA and significant difference in resting T/M ratio in group 6 compared with groups 1 and 3 (group 1 vs 6 and group 3 vs 6, $P < .05$) (Table 4) suggest that there might be differences in their role of maintaining the mandibular posture between the temporal and masseter muscles.

Why was there higher resting TMA in group 6 than in other groups and no difference in resting MMA among all groups in Table 4? The morphological pattern of Class III malocclusion usually shows a well-developed mandibular body or ramus. Changes in the muscular action axis and increases in the gravitational component in Class III malocclusion might cause a higher stimulation of neuromuscular spindles of the temporal muscle than those of the masseter muscle, and it turns out to be a higher resting TMA.[14] Because Bakke and Michler[35] reported that the relative loading of the muscles was markedly increased during resting posture, the small difference of resting TMAs (roughly 4 μV in group 6 compared with 2 μV in other groups) could be related with establishment of Class III malocclusion and a hyperdivergent type. Because resting masticatory muscle activity is related to the form and position of the mandible, there might be a difference between the temporal and masseter muscles in their role of maintaining the mandibular posture.

In terms of the correlation between TMA and facial type, in the Class III group there were significant positive correlations between resting TMA and SN-GoMe ($P < .05$) and a significant negative correlation between clenching TMA and ANB ($P < .05$) (Table 5). In the hyperdivergent group, the resting T/M ratio was negatively correlated with ANB ($P < .05$) (Table 5). These findings mean that the resting TMA increased according to increases of hyperdivergency (SN-GoMe). They also mean that clenching TMA and resting T/M ratio increased according to increases in the Class III tendency (decrease of ANB) in the Class III group and in the hyperdivergent group, respectively. Therefore, hyperdivergency and Class III malocclusion might have a significant effect on resting and clenching TMA.

Although clenching TMA did not show correlation with SN-GoMe in our study, Möller[1] and Ingervall[36] reported a negative correlation between mandibular plane angle and clenching TMA. Bakke and Michler[35] reported that maximal voluntary clenching was positively correlated to molar contact and negatively to anterior face height, mandibular inclination, vertical jaw relation, and gonial angle.

The findings that there were no significant differences in resting and clenching MMA among all groups (Table 4) and no significant correlation between MMA and facial type (Table 5) suggest that MMA does not have a major influence on the skeletal facial type.

Miralles et al[14] and Rodrigues and Ferreira[37] reported that the sagittal relationship of malocclusion did not show any difference in clenching MMA, which confirms our results. In our study, the skeletal vertical facial types did not show any difference in clenching MMA (Table 5). However, significant negative correlation between MMA and vertical measurement such as the mandibular plane angle, ratio of anterior to posterior facial height, and gonial angle has been reported.[1,4,16,38] The cross-sectional area of the masseter muscle measured by ultrasonography was negatively correlated to the vertical facial height.[39–41]

To resolve the controversies about correlation between the muscle activity and skeletal facial type, it is necessary to perform multicenter studies with enough sample size and accurate measurement of muscle activity at rest and during function.

CONCLUSIONS

a. The more Class III malocclusion tendency, the more hyperdivergent tendency, the higher resting

TMA, and the lesser increase of clenching MMA were expressed.

b. Resting MMA did not have a major influence on the skeletal facial type as did hyper- or normodivergent patterns with various sagittal relationships.

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